Dynamic Ambient Noise Model Comparison with Point Sur, California, *In Situ* Data

by Charlotte V. Leigh[1] and Anthony I. Eller[2]

[1] *Applied Physics Laboratory, University of Washington, Seattle*
[2] *Science Applications International Corporation, McLean, Virginia*

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Applied Physics Laboratory   University of Washington
1013 NE 40th Street   Seattle, Washington 98105-6698

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1. INTRODUCTION

This analysis was conducted to provide benchmarked performance of the Dynamic Ambient Noise Model (DANM) Version 1.0 against both *in situ* ambient noise (AN) measurements collected in 1998 offshore Point Sur, California, and against predicted AN spectrum levels computed with the Ambient Noise Directionality Estimation System (ANDES).

First, the Point Sur data set is characterized. Next, the DANM Version 1.0 model and the ANDES model configurations are described. The first performance analysis evaluates the omni-directional predictive capabilities of DANM and ANDES. For omni analysis, the DANM and ANDES shipping components are calculated from shipping density databases. Planned for future analysis is an assessment of the directional predictive capabilities of the DANM and ANDES models. For this planned analysis, the shipping component is calculated from both the shipping density database and discrete ship tracks.

2. POINT SUR *IN SITU* DATA DISCRIPTION

The Point Sur hydrophone array, a decommissioned U.S. Navy Sound Surveillance System (SOSUS) receiver, is located approximately 40 km west of Point Sur, California, (36º17.948'N, 122º23.631'W) at 1359 m depth within the Monterey Bay National Marine Sanctuary (Figure 1).

2.1 Acoustic Data

APL-UW has collected nearly continuous measurements of AN spectral densities at the Point Sur array from June 1994 through January 2001. These ambient noise spectral densities, which characterize the composite AN background including wind generated, oceanic ship traffic, and biologic noise levels, have been used to establish level probability of occurrence, whale call dominance, ship-like signature dominance, and other statistics. The Point Sur dataset is well suited for investigating level variability over time scales greater than about 5 min and for comparison with ambient noise models that explicitly model both wind generated and oceanic ship traffic. DANM employs the Historical Shipping Density Database (HITS) version 4.0 for shipping density levels. This database relied extensively on shipping levels recorded in 1998 by Lloyds of London. *In situ* measurements for 1998 at Point Sur, California, were selected as the best chronological match to the source data for HITS 4.0.

Andrew et al. [2002] compare ambient ocean sound data for a receiver on the Point Sur Array collected from 1994 to 2001 with data collected on the same receiver from 1963 to

1965. After establishing an appropriate basis for direct comparison, Andrew measured an ambient noise increase across the spectrum 10–500 Hz as follows: approximately 10 dB in median sound level between 20 and 80 Hz; approximately 3 dB in median sound level at 100 Hz and vicinity; approximately 3 dB at 200–300 Hz; and approximately 9 dB above 300 Hz.

Figure 1. Array location, bathymetry, and Monterey Bay National Marine Sanctuary boundary

The analysis of *Wenz* [1962] defines and differentiates ship noise and oceanic traffic noise. He notes that ship noise from one or more ships close by was usually obvious, was decipherable by temporary narrow band components, had comparatively rapid noise level rise and fall, and was generally deleted from AN. Wenz defined oceanic traffic noise as resulting from the combined effect of all ship traffic, except ship noise. *Andrew et al.* [2002] established that *Wenz's* [1962] processing, presumably applied to eliminate transient effects from nearby ships, produced a result that is indistinguishable from the median (50th percentile) levels.

2.2 Acoustic Environment

The Point Sur array was sited for expansive exposure to ship noise throughout the Pacific Basin (Figure 2). The array is exposed to ambient noise from multiple regions and transit routes.
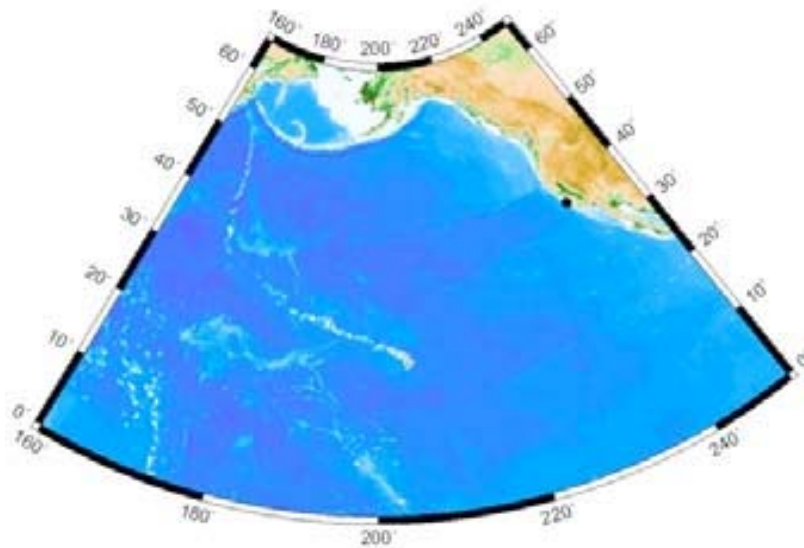

Figure 2. Point Sur array (black dot) Pacific Basin exposure

The array, anchored southwest of Sur Ridge, is exposed to both coastal oceanic traffic noise and to coastal ship noise generated by ships transiting west of the array. It is masked partially by Sur Ridge to coastal ships transiting inshore of the ridge (Figure 3).
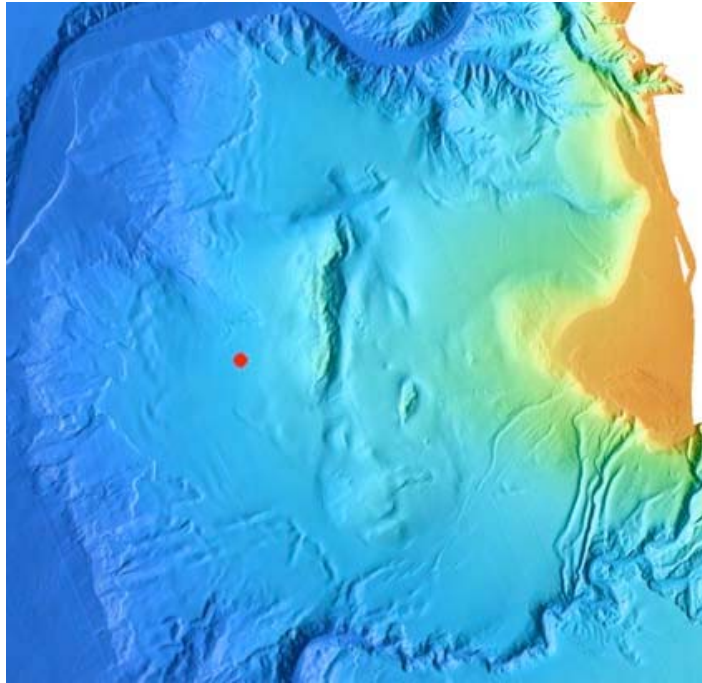
Figure 3. Sur Ridge and Point Sur array (red dot)

2.3 Vessel Traffic and Traffic Lanes

In 1993 the San Francisco Vessel Traffic Service, part of the U.S. Coast Guard, established the San Francisco Regulated Navigation Area (RNA) to improve control of vessel traffic. The RNA regulates the circumscribed area outside the San Francisco Bay entrance and prescribes traffic lanes for vessels transiting north, west, and south (Figure 4).
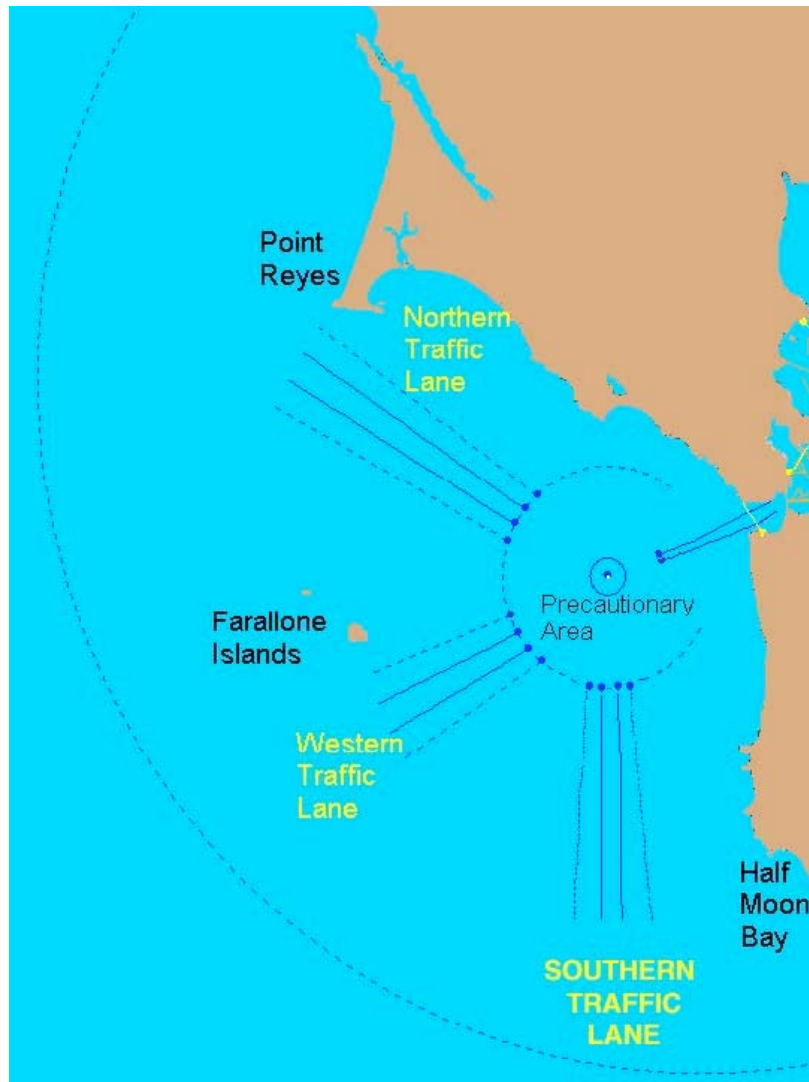
Figure 4. San Francisco Regulated Navigation Area

Point Sur is well positioned to receive underwater sounds from those vessels entering into or exiting from San Francisco Bay via the southern or the western traffic lanes. Of particular interest were those vessels transiting the southern traffic lane as these vessels likely transited along the southern California coast. The U.S. Coast Guard provided records of those vessels transiting the southern traffic lane from 1989 through 1996 for this analysis. The classifications shown in Table 1 are those tabulated by the Vessel Traffic Service [*U.S. Coast Guard*, 1999].

Table 1. Vessels transiting the southern traffic lane 1989–1996

Type Vessel	1989	1990	1991	1992	1993	1994	1995	1996
Commercial	5,761	5,877	5,876	4,959	5,085	5,515	5,082	4,925
Hazardous	95	83	97	157	86	77	76	87
U. S. Navy	2,236	1,913	1,823	1,330	854	651	540	267
Coast Guard	2,572	1,907	1,788	1,650	1,400	1,323	2,052	1,556
Submarines	67	70	69	61	79	56	54	18
Foreign Navy	45	59	49	51	39	30	31	44
Tugs without Tow	868	525	517	442	361	910	1,968	1,994
Tugs with Tow	13,790	14,553	13,085	12,812	13,937	11,764	15,735	15,666
Deep Draft	248	205	230	237	265	298	206	188
Ferries	56,036	58,343	56,580	54,439	59,967	56,478	59,341	66,290
US Government	935	1,081	904	1,066	737	841	911	980
Non-channel 13	532	310	236	514	693	707	679	618
Dredges	2,819	2,390	1,914	2,255	3,100	1,563	1,393	2,063
Tankers	3,907	3,684	3,570	3,537	3,681	3,224	2,737	2,848
Passenger Ships	65	70	157	102	163	136	281	319
TOTALS	89,976	91,070	86,895	83,614	87,447	83,573	91,086	97,863

Prior to 2000 southern California coastal shipping lanes were not regulated south of the San Francisco southern traffic lane termination point at 37°47'18"N. Anecdotal information suggests that container ships transit close ashore while tankers transit approximately 50 n mi offshore to avoid inshore traffic. In July 2000 the International Maritime Organization (IMO) established new shipping lanes and port routes (Figure 5) to protect the Monterey Bay National Marine Sanctuary [*Environmental News Network*, 1998].

Available information suggests that in 1998 tankers transited approximately 30 n mi west of the array while container shipping transited 5–15 n mi east of the array. Although the Sur Ridge partially masked ships transiting to the east, the array was fully exposed to those ships transiting offshore to the west.
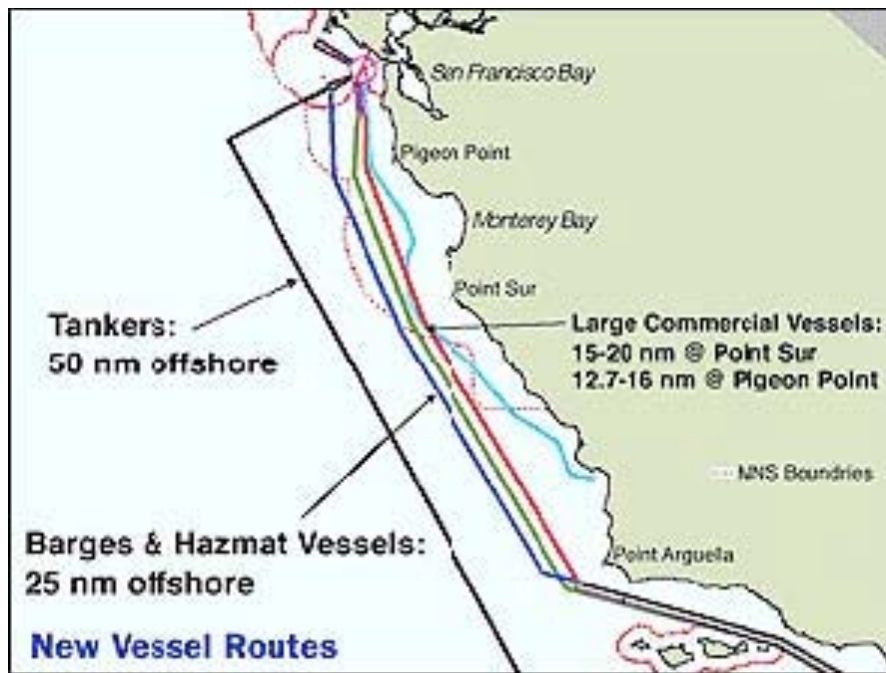
Figure 5. Mid-California north–south coastal shipping routes prescribed by the IMO
[*Environmental News Network*, 1998]

2.4 Point Sur Data Processing and Data Distribution

The Point Sur dataset has been calibrated to give all reported noise measurements in dB re 1 μPa²/Hz [*Andrew*, 2000]. Three minutes of data collected each 5 or 6 min produced autospectral estimates over 1–500 Hz in 1-Hz bins. These data were synthesized in one-third octave passbands in the power domain. Also, the median, mean, and other measures of central tendency were computed in the power domain. Three months were selected for comparison: the January (7,087 samples), April (4,260 samples), and July (6471 samples) datasets. Figures 6 and 7 are histograms of the 7076 spectra for January 1998 and illustrate the *in situ* sample distribution.
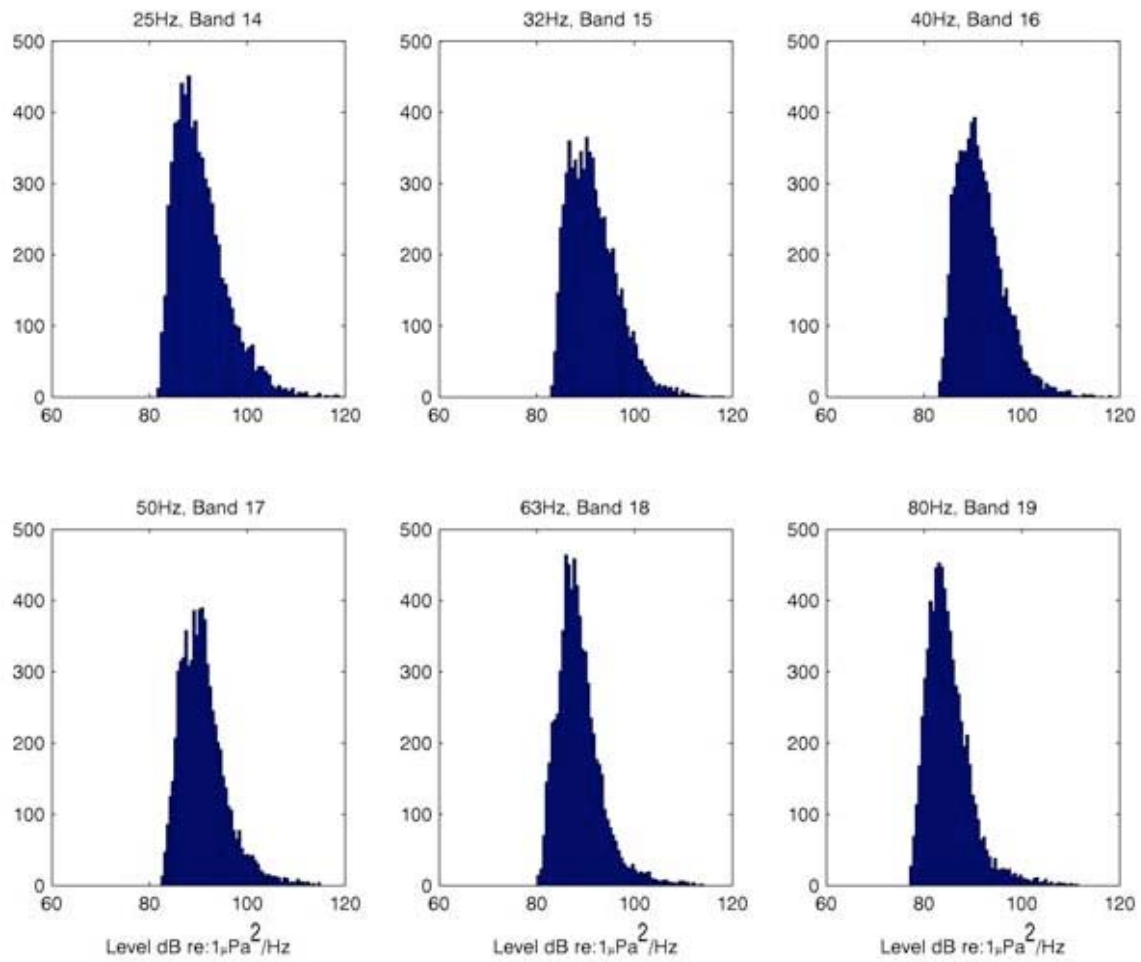
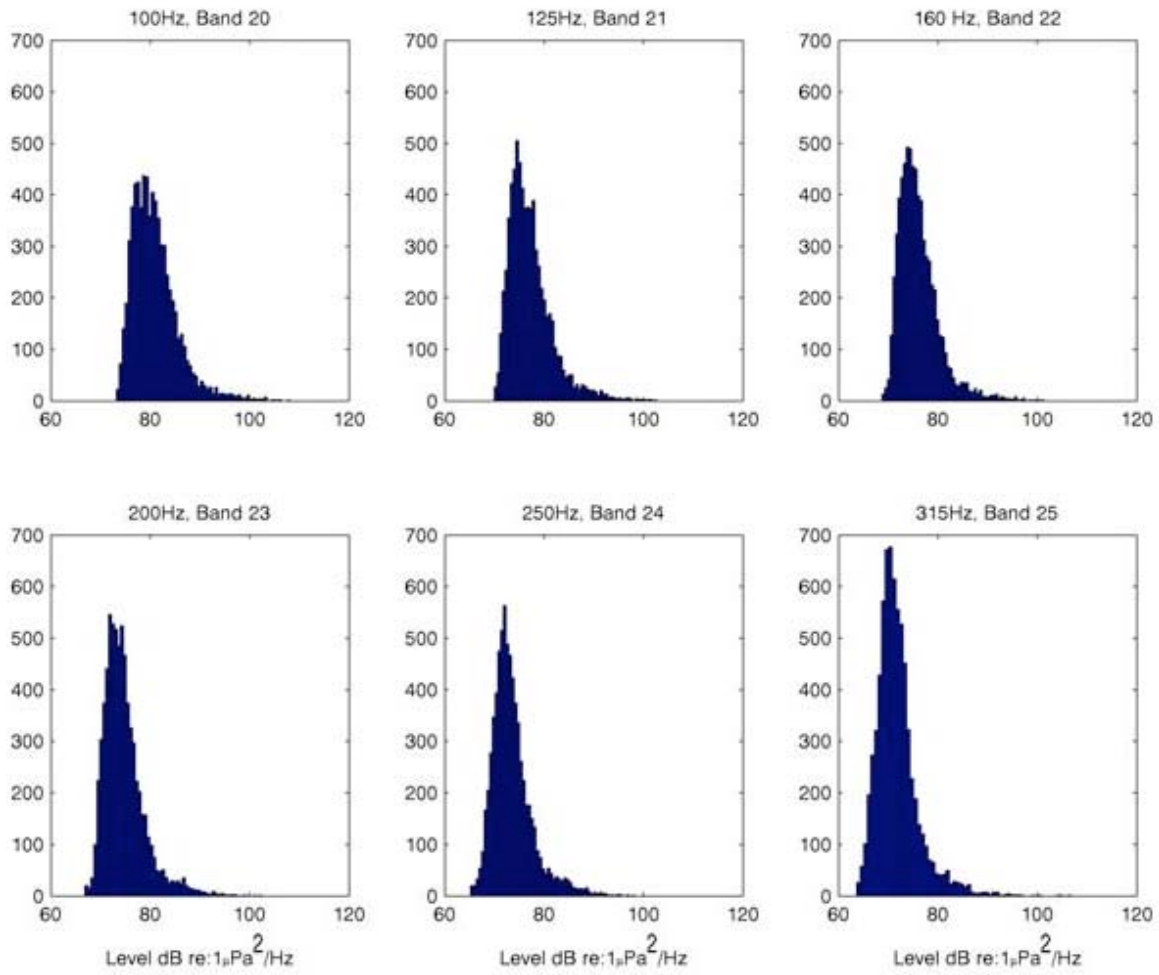Figure 6. Histograms of one-third octave passbands 14–19

Figure 7. Histograms of one-third octave passbands 20–25
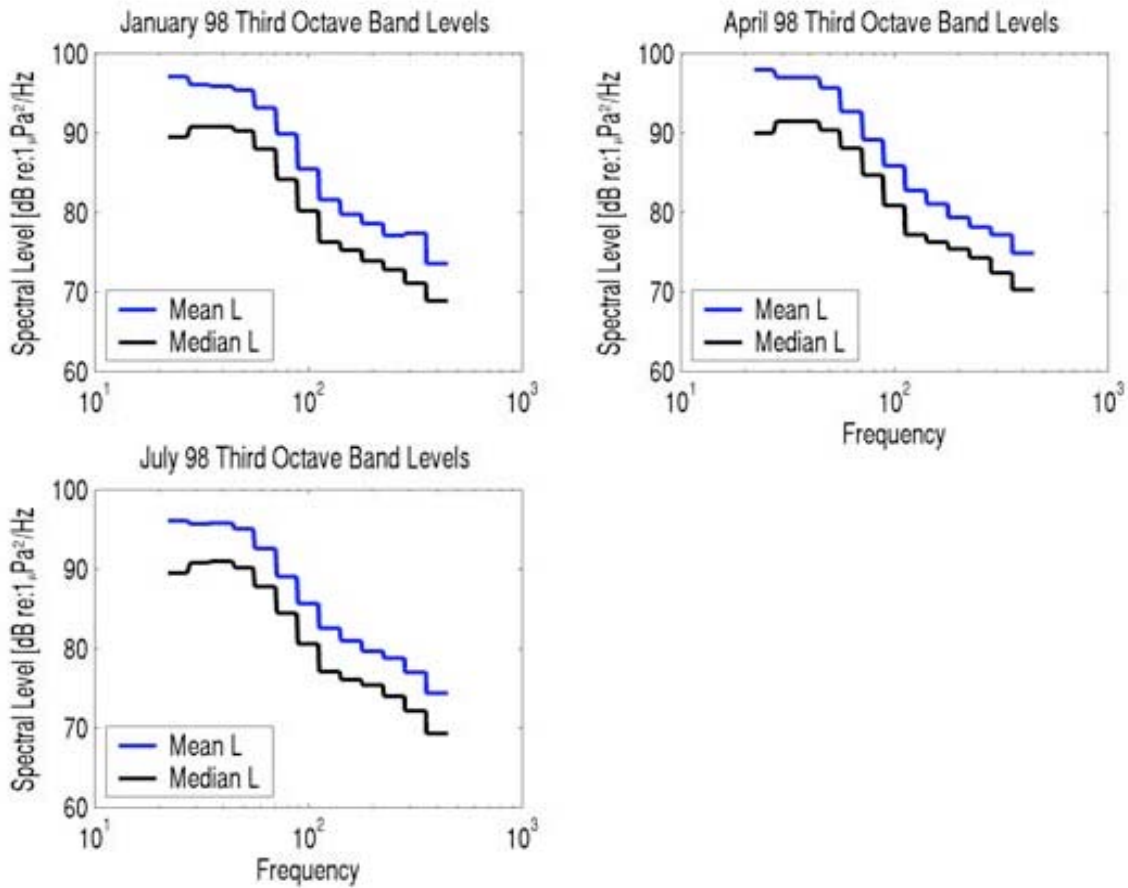
Figure 8. Point Sur median and mean one-third octave passband levels

3. THE DYNAMIC AMBIENT NOISE MODEL (DANM)

Initially developed in the late 1990s, DANM V-1.0 [*Hall*, 2001] computes time-dependent horizontal noise directionality in support of U.S. Navy SONAR operations. The computed time-dependent horizontal noise directionality includes modeled ambient wind and shipping noise. Required environmental parameters include shipping source levels, shipping densities, bathymetry, sound velocity profiles, ocean bottom type, and winds. Transmission loss is computed with either the parabolic equation model or the astral model.

DANM V-1.0 was configured as detailed in Table 2. Of note, the HITS 4.0 Merchant Shipping Densities were assembled from Lloyds of London 1998 shipping records and a predictive ocean route model [*Emery et al*., 2001]. DANM calls these densities to synthesize level-versus-time data for hypothetical receivers. At low frequencies dominated by shipping, DANM should reproduce approximately the same levels seen in Point Sur 1998 measurements. All DANM levels were provided by T. Hall of Planning Systems, Inc.

Table 2. DANM configuration

DANM Parameters	
Latitude:	36º 17' 56" N entered as 36.30
Longitude:	235.6º E entered as −122.39
Months:	January, April, July
Depth:	1359 meters entered as 4459 feet
TL Radial:	0–360 in 5° steps
TL range:	500 NM
TL model:	Parabolic Equation V5.1, Astral V-5.0
Wind Data:	Omni Winds SMGC V-1.0
Ship Positions:	Filename 0.0 (set for zero)
Ship Positions:	Distance 0.0 NM (set for zero)
Supporting Models and Databases	
Bathymetry:	DBDBV level 0 dated 11/24/2000
Sound Velocity Profile:	GDEM dated 4/3/2000
Historical Shipping:	HITS V-4.0 dated 5/2002
Historical Winds:	SMGC dated as 4/21/1998
Historical Bottom:	LFBL V-10.0 Not used

DANM incorporates broadband source levels [*Renner*, 1986] for four classes of ships: tankers, merchants, larger tankers, and super tankers. Table 3 delineates the source levels used in the DANM computations; in all cases the default speed is 12.7 kt.

Table 3. DANM source levels

DANM SL Model   (Courtesy T. Hall)

Freq.	Super Tanker	Large Tanker	Merchant Source Level	Small Tanker	Fishing
5	190.3	186.3	177.3	168.3	159.3
7.1	188.9	184.9	175.9	166.9	157.9
10.0	187.5	183.5	174.5	165.5	156.5
14.1	186.1	182.1	173.1	164.1	155.1
20.0	184.7	180.7	171.7	162.7	153.7
28.3	183.3	179.3	170.3	161.3	152.3
50.0	181.0	177.0	168.0	159.0	150.0
50.0	181.0	177.0	168.0	159.0	150.0
70.7	176.3	172.3	163.3	154.3	145.3
100.0	171.5	167.5	158.5	149.5	140.5
141.4	166.8	162.8	153.8	144.8	135.8
200.0	162.0	158.0	149.0	140.0	131.0
282.8	157.3	153.3	144.3	135.3	126.3
400.0	152.5	148.5	139.5	130.5	121.5

4. THE AMBIENT NOISE DIRECTIONALITY ESTIMATION SYSTEM (ANDES)

Initially developed in the early 1980s, ANDES is a U.S. Navy legacy ambient noise model. Computed time-dependent horizontal noise directionality includes modeled ambient wind and shipping noise. Required environmental parameters include shipping source levels, shipping densities, bathymetry, sound velocity profiles, ocean bottom type, and winds. Transmission loss is computed with the astral model.

The ANDES configuration is shown in Table 4. Of note, ANDES incorporates different source levels [*Jennette*, 1993] and uses an earlier source of shipping densities (HITS 3.2). Environmental parameter sources are similar with one exception: ANDES does not use the SMGC wind database. The user is responsible for setting the wind speed parameter. Last, ANDES incorporates an earlier form of the ASTRAL transmission loss model in a software design that prohibits migration to more recently developed transmission loss models for this test. All ANDES levels were provided by A. Eller.

Table 4. ANDES configuration

ANDES Parameters	
Latitude:	36º 17' 56" N (36.30)
Longitude:	122º 23' 38" W (–122.39)
Months:	January, April, July
Depth:	1359 meters entered as 4459 feet
TL Radial:	0–360 in 20-degree increments
TL range:	8000 Nautical Miles
Winds:	11 Knots January, 10 Knots April, July
Supporting Databases & Models	
Bathymetry:	DBDBV level 0 dated 11/24/2000
Sound Velocity Profile:	Provinced GDEM
Historical Shipping Densities:	HITS V-3.2
Historical Winds:	User Input
Historical Bottom:	LFBL V-9.1
Transmission Loss:	Astral V-4.1

5. MODEL–DATA COMPARISONS

Point Sur one-third octave passband median levels and mean levels are compared to levels predicted by DANM and to levels predicted by the older ANDES. DANM ambient noise levels were computed with the parabolic equation transmission loss model (DANM PE) and with the ASTRAL transmission loss model (DANM AS) at the one-third-octave frequencies for January, April, and July.

5.1 Median Levels: DANM PE, DANM AS, Point Sur *in situ* Passband

Both DANM PE and DANM AS closely predicted observed *in situ* median levels (Figures 9–11).
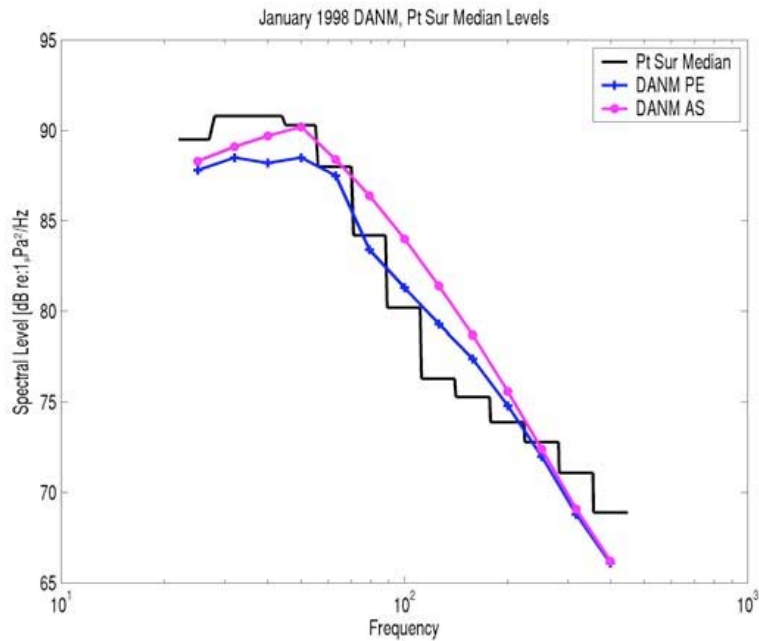
Figure 9. Mean DANM predictions compared to Point Sur *in situ* passband median levels for January 1998
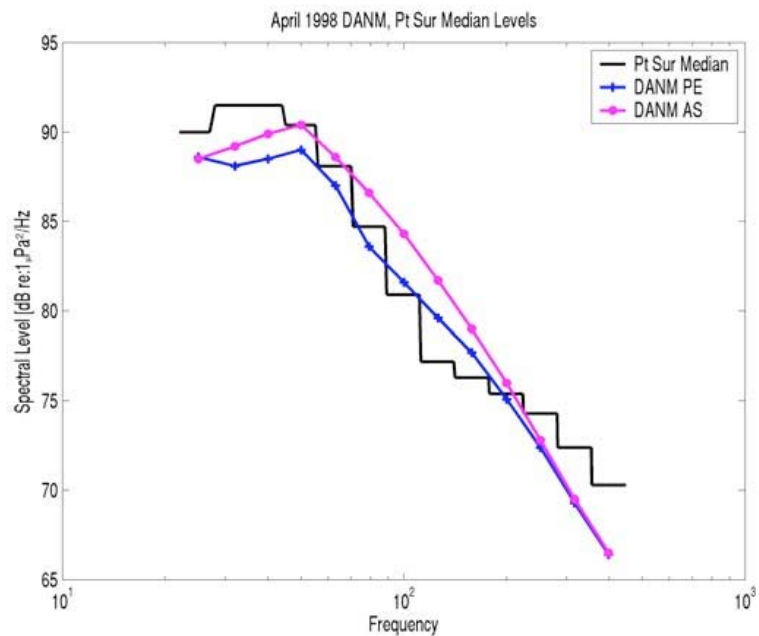

Figure 10. DANM compared to Point Sur *in situ* passband median levels for April 1998
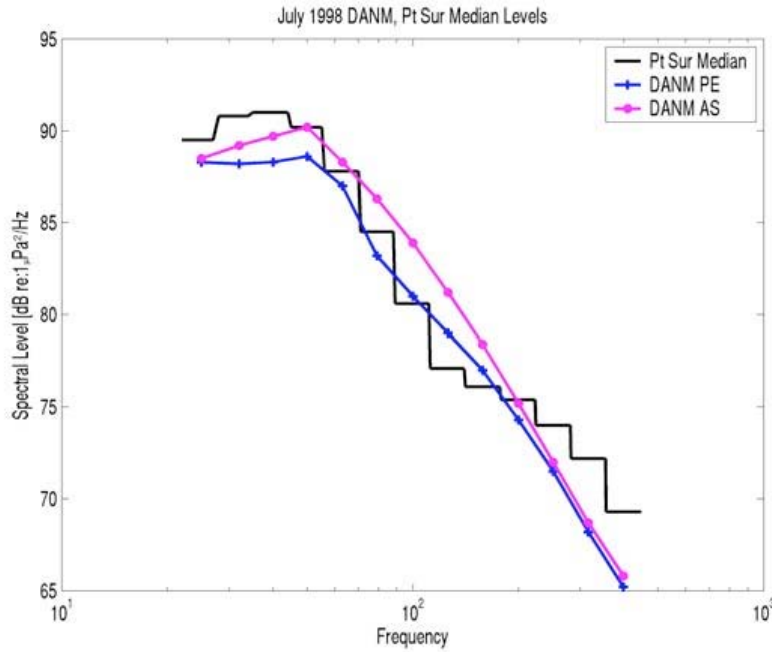
Figure 11. DANM compared to Point Sur *in situ* passband median levels for July 1998

Both DANM AS and DANM PE predicted levels for the third octave center frequencies for January lie within 3 dB of the included one-third octave passband median levels. In general, the DANM PE predictions were closer to the measured data. Predicted DANM AS and DANM PE levels for April and July passband median levels lie within 4 dB of the observed levels.

5.2 Median Levels: DANM AS, ANDES AS, Point Sur *in situ* Passband

DANM AS and ANDES were compared with the Point Sur synthesized one-third octave passband median levels. A comparison of DANM PE with ANDES was not conducted, as ANDES values with PE were not available. These comparisons showed (Figures 12–14) that for most cases ANDES predicted higher AN levels below 80 Hz. Above 80 Hz, DANM predicted levels were higher.
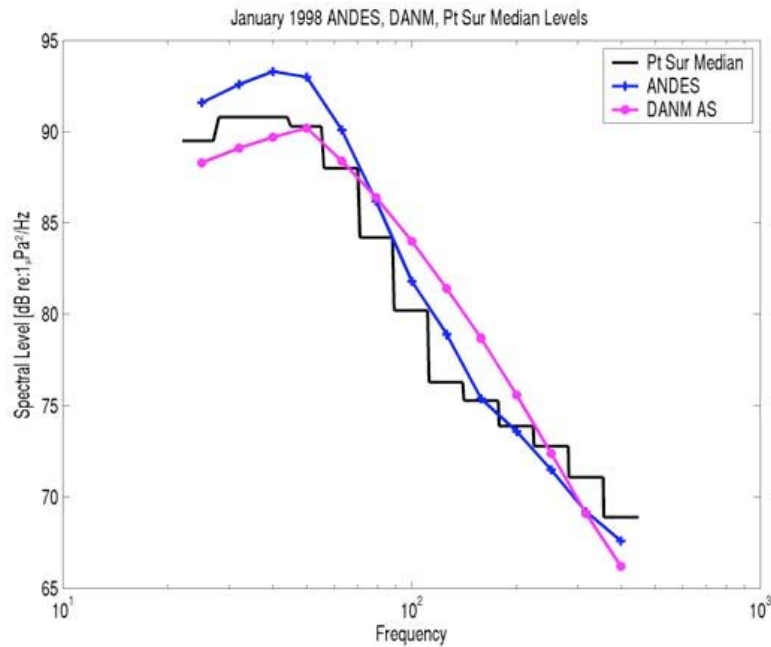
Figure 12. Median levels: ANDES, DANM, and Point Sur *in situ* passband for January 1998
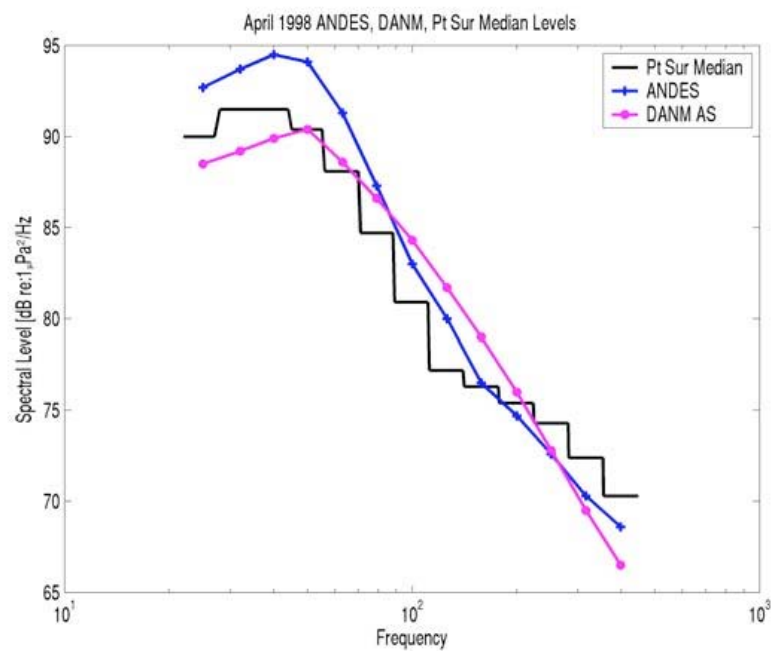

Figure 13. Median levels: ANDES, DANM, and Point Sur *in situ* passband for April 1998
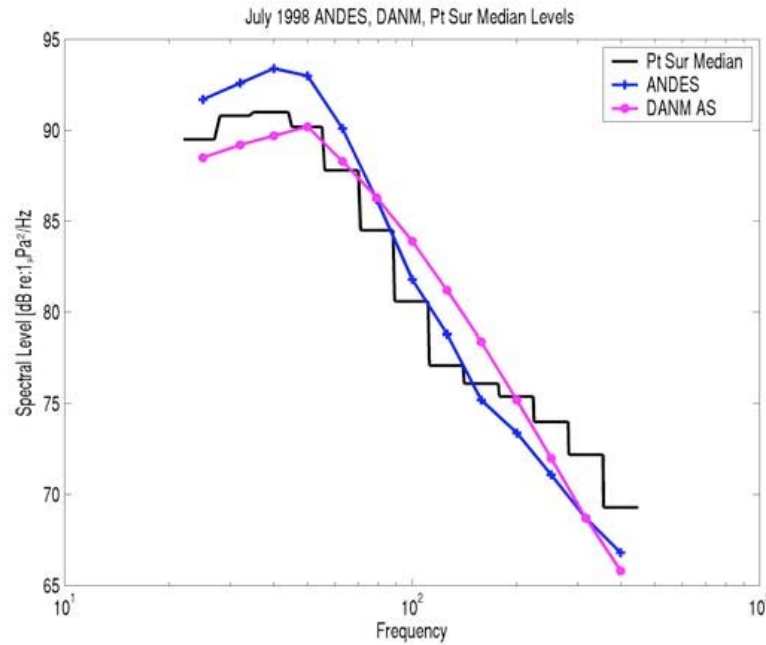
Figure 14. Median levels: ANDES, DANM, and Point Sur *in situ* passband for July 1998

For the one-third octave center frequencies in January, April, and July, both DANM AS and ANDES levels closely predicted *in situ* median levels (Table 5).

Table 5. Difference between modeled and median levels (dB)

Frequency	January		April		July	
	ANDES	DANM	ANDES	DANM	ANDES	DANM
25	2	-1	3	1	2	1
32	2	-2	2	2	2	2
40	3	-1	3	2	2	1
50	3	0	4	0	3	0
63	2	0	3	0	2	1
80	2	2	3	2	2	2
100	2	4	2	3	1	3
125	3	5	3	4	2	4
160	0	3	0	3	1	2
200	0	2	1	1	2	0
250	1	0	2	1	3	2
315	2	2	2	3	3	3
400	1	3	2	4	3	4
Mean Delta	**1.77**	**1.92**	**2.31**	**2.00**	**2.15**	**1.92**

The predicted DANM AN levels were in closer agreement with the observed data in April and July while ANDES was a slightly better fit than DANM in January.

5.3 Mean Levels: DANM PE, ANDES AS, Point Sur *in situ* Passband

The predicted mean DANM PE and DANM AS levels did not agree favorably with the one-third octave *in situ* mean passband levels (Figures 15–17).
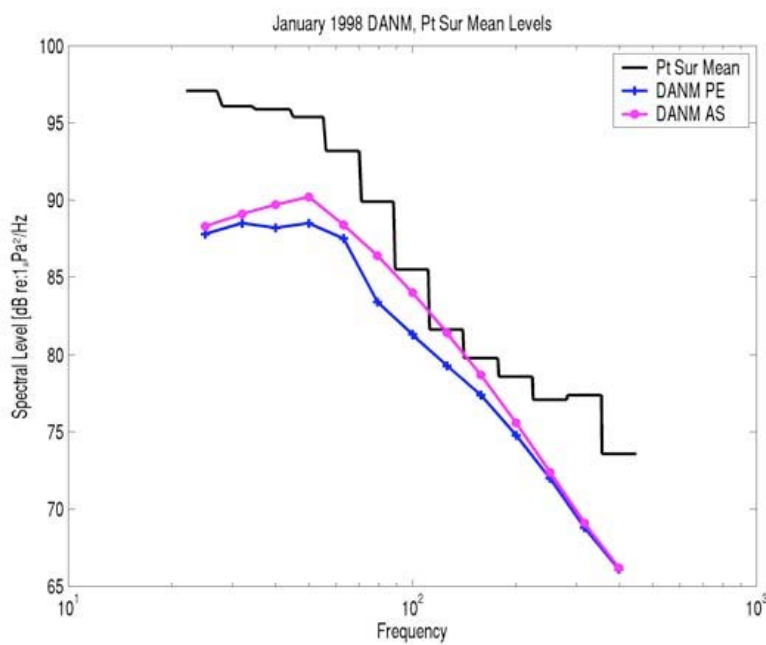

Figure 15. Mean levels: DANM PE, DANM AS, and Point Sur *in situ* passband for January 1998
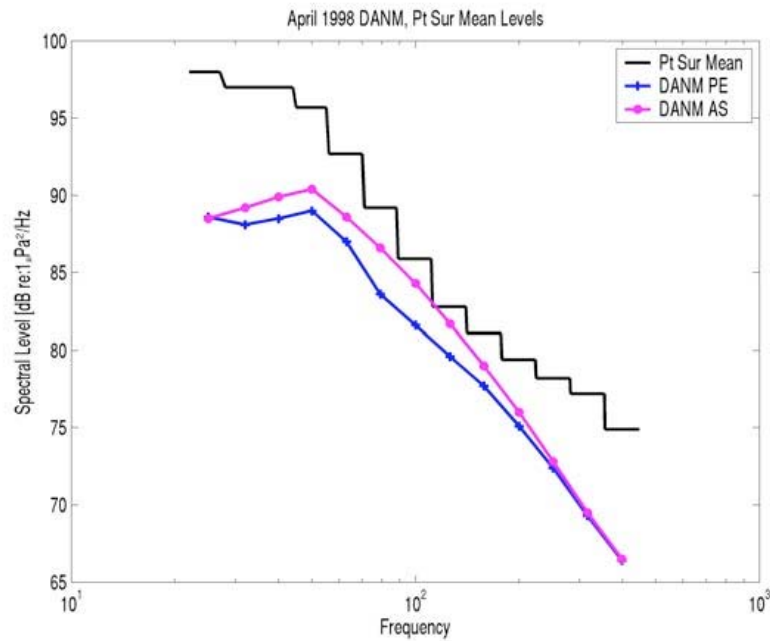
Figure 16. Mean levels: DANM PE, DANM AS, and Point Sur *in situ* passband for April 1998
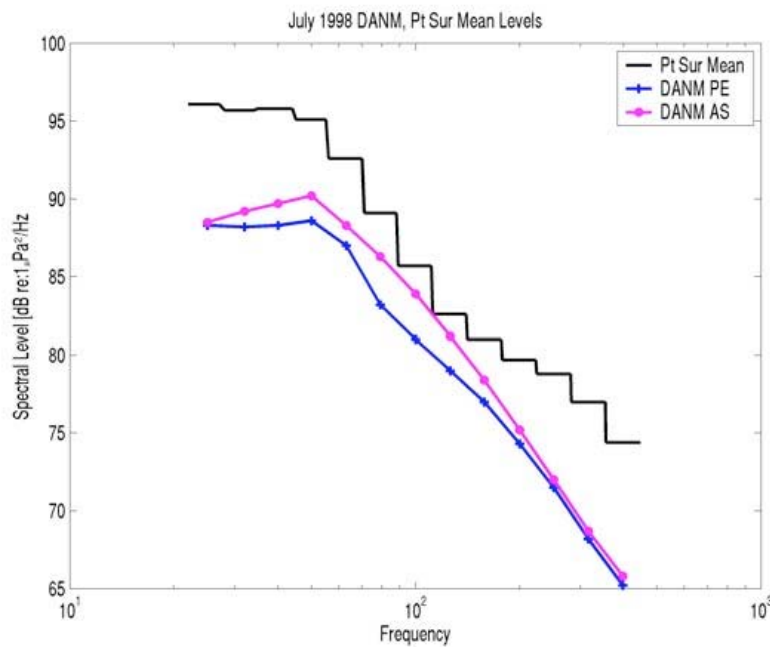

Figure 17. Mean levels: DANM PE, DANM AS, and Point Sur *in situ* passband for July 1998

Both DANM AS and DANM PE predicted levels for the one-third octave center frequencies for January, April, and July lie within 9 dB of the included Point Sur one-third octave passband mean levels.

5.4 Mean Levels: DANM AS, ANDES AS, Point Sur *in situ* Passband

Figures 18–20 compare DANM AS and ANDES predictions to synthesized Point Sur one-third octave passband mean levels. Observe (Figure 18) that ANDES predicted levels are closer between 25Hz and 64Hz; DANM and ANDES predict approximately the same level at 80Hz; while between 80Hz and 250Hz, DANM predicted levels are closer.
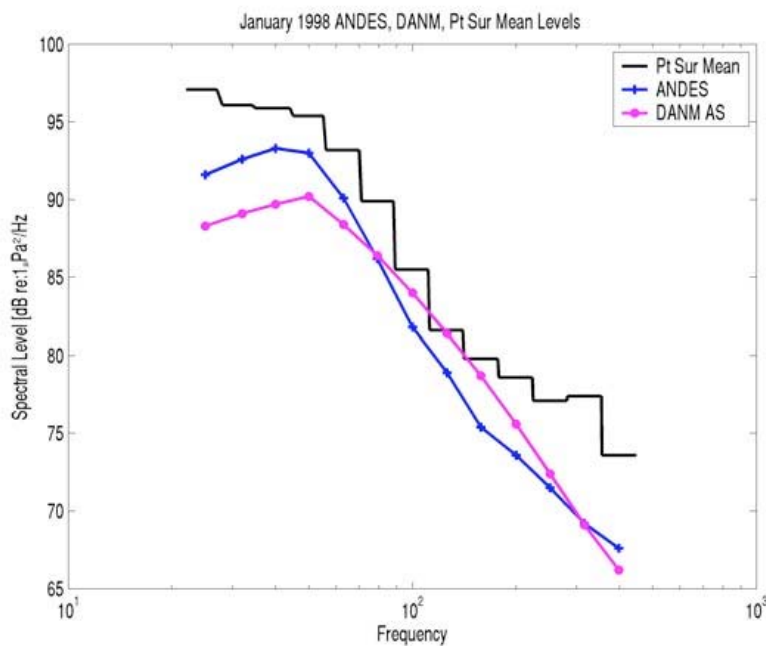

Figure 18. Mean levels: DANM AS, ANDES, and Point Sur *in situ* passband for January 1998
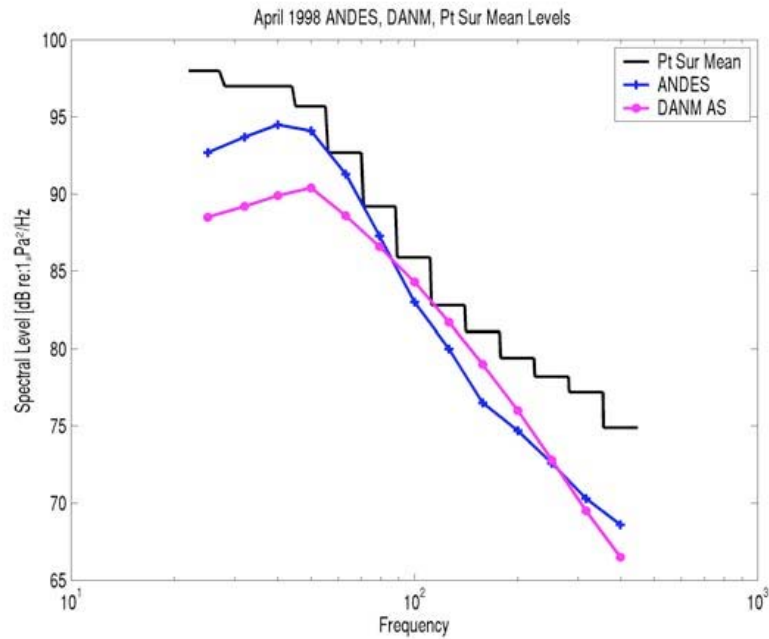
Figure 19. Mean levels: DANM AS, ANDES, and Point Sur *in situ* passband for April 1998
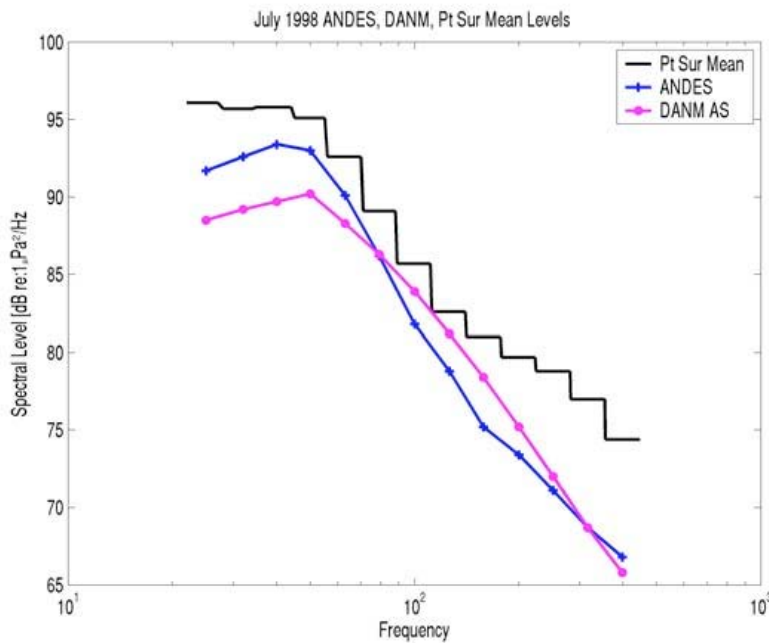

Figure 20. Mean levels: DANM AS, ANDES, and Point Sur *in situ* passband for July 1998

6. CONCLUSIONS

DANM AS, DANM PE, and ANDES closely predict the synthesized one-third octave passband median levels compiled from the Point Sur *in situ* data. All predictions presented here are based on the use of shipping densities. DANM, as part of DAPS, offers the further capability, not evaluated here, of using discrete ship representations to simulate ambient noise statistics. In general, the ANDES predictions were closer to the observed values at frequencies less than 80 Hz. DANM was closer to the observed values at frequencies above 80 Hz.

Two aspects of these results warrant further investigation. First, ANDES predictions of shipping noise are substantially higher than the corresponding predictions by DANM at frequencies below 80 Hz. This may result from differences in the shipping densities extracted from the shipping databases used by the two models in the vicinity of Point Sur, or possibly from differences in the source level models used. Second, model predictions presented here compare better with median data than with intensity-averaged mean data. It has been suggested, however, that noise predictions based on shipping densities should be comparable to intensity-averaged mean data. These two questions need to be resolved.

7. RECOMMENDATIONS

DANM uses HITS V-4.0, a database that uses statistics-based algorithms that vary shipping densities in timeframes on the order of minutes as opposed to months. While HITS V-4.0 predicts an increase in total shipping (as expected), ANDES was expected to under-predict noise levels at the low frequencies dominated by shipping when compared to Point Sur *in situ* data. After extensive analysis, it was determined that DANM employed an earlier suite of source levels while ANDES employed a much later suite. The dominant role that source level has exercised in these comparisons will be resolved with migration to U.S. Navy standard source levels developed by Stephen Wales.

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14. SUBJECT TERMS

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